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BPH5 Human perception and new indicator, 23rd July

Prediction of outdoor human thermal states in non-uniform thermal loads

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Outline

1. Introduction
    - Background
    - Aim
2. Method / Experiments
    - Energy balance
    - Measurement
        - －environment, human
3. Summary

Introduction

Our location

Okayama
- 34° 39N, Western Japan
- 0.7 million urban population
- highest mean maximum temp. in summer in the nation-wide

→known as sunny region,
"Nagi" = calm wind

▲Downtown Okayama

▲Historical area

Background

- People prefer to stay (semi-)outdoor.
  - Enjoying warm sun, fresh air, landscape etc.

Concerns about health effects of severe environment…

Hot-Humid region such as Asian countries

Background

- We experience complex thermal environment in outdoor; spatial and temporal non-uniformity.

Influential variables;
Air temperature, Humidity, Radiation, Air speed, Metabolic heat, Clothing

Environment

Human

Required different approach from conventional assessment approach

Background

- Greater potential of radiation/radiation-properties of material to change people's thermal experiences

Properties of surfaces
-ground, wall …clothing

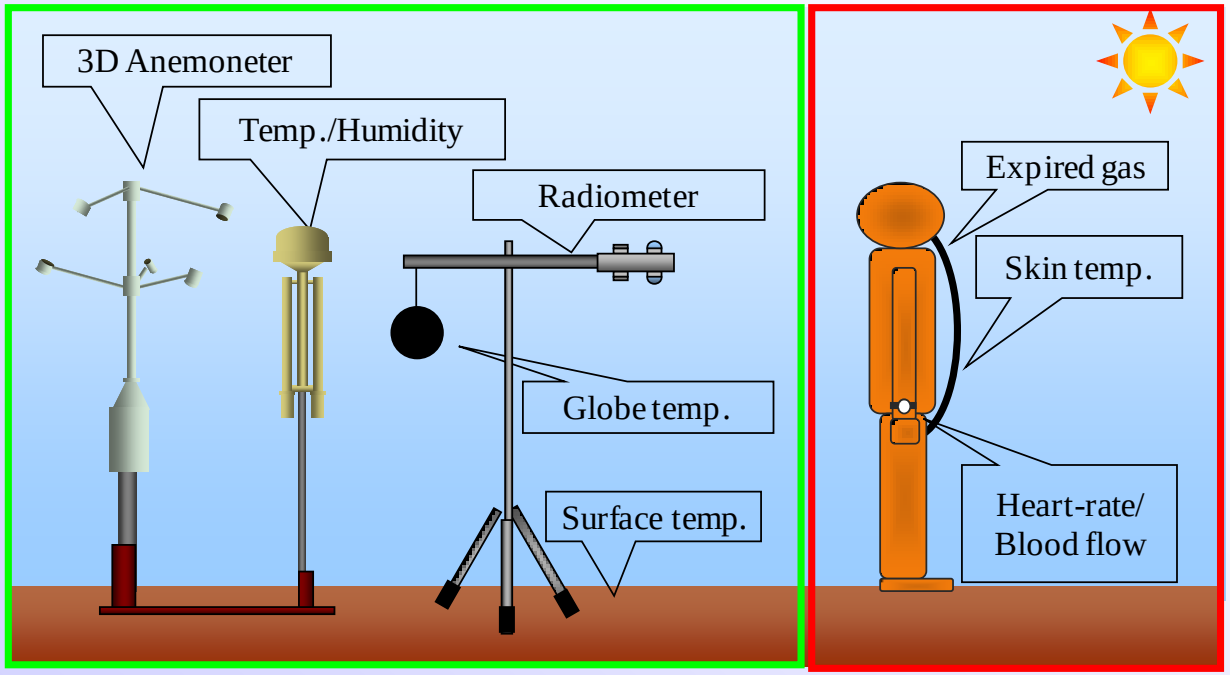
No solid method for complex radiative environment

Aim

- Quantitatively determining human thermal states in outdoor under complex environment

Outdoor Human

Non-uniformity



By measuring both environment and human for maintaining good health and performance

Method / Experiment

Human energy balance

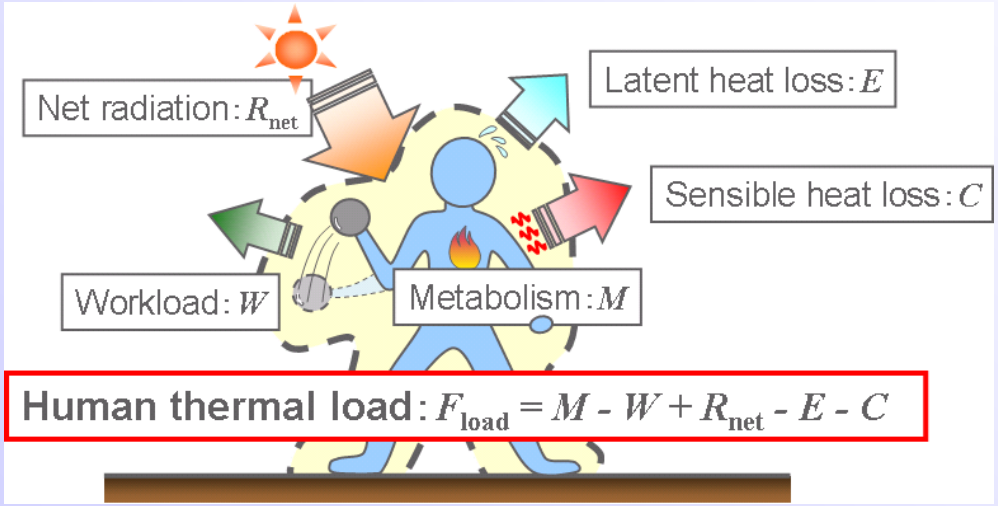
Major factors in the proximity of humans

- Environmental information
  (Air temp. Humidity Radiation Air movement)
- Human information
  (Metabolism Clothing)

Human Thermal Load
[W/m^2]

$$F_{load} = M - W + R_{net} - E - C$$

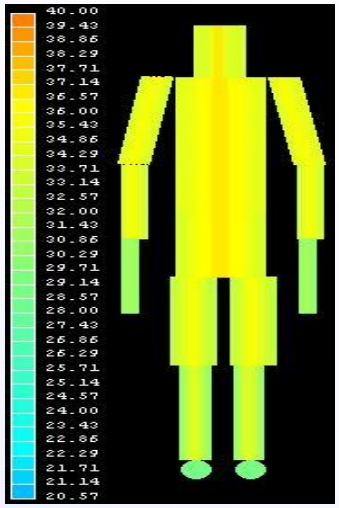
F_{load}	Thermal load
M	Metabolism
W	Workload
R_{net}	Radiation
C	Sensible heat loss
E	Latent heat loss

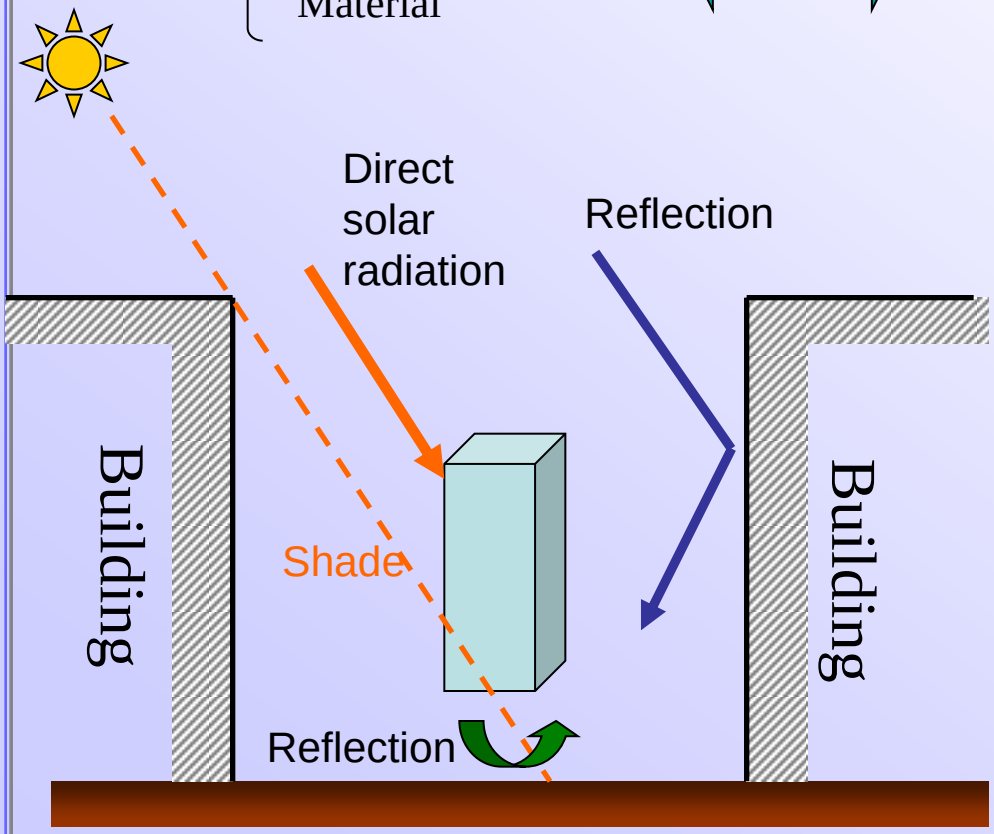


Expression of complexity（Non-uniformity）

- Environment
  - Structure
  - Material

- Human
  - Sensitivity
  - Distribution

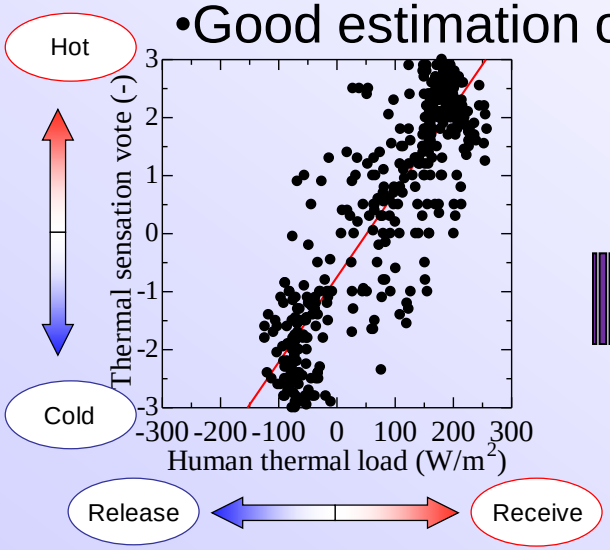


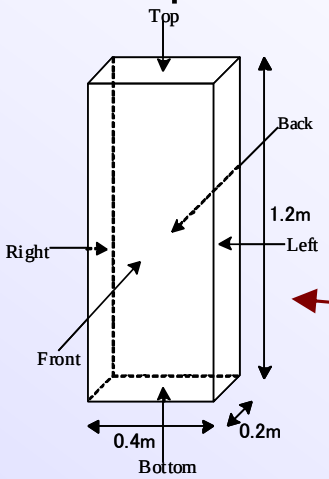


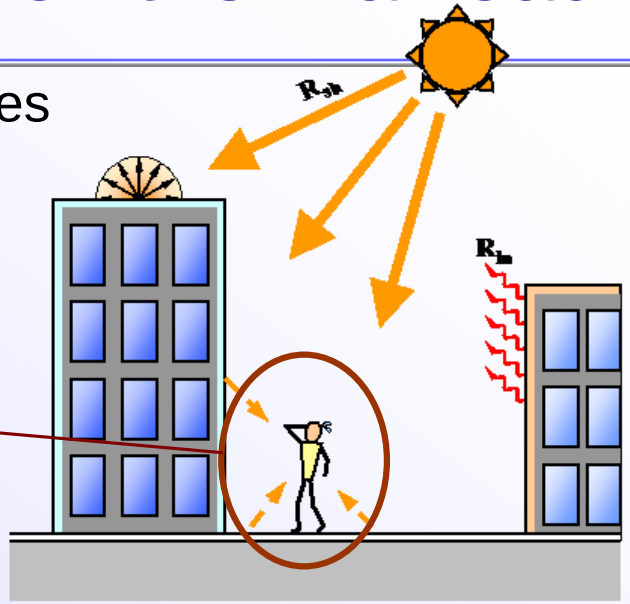
Step 1; Measurements
Step 2; Simulations
Step 3; Applications

Effect of radiative properties on thermal load

•Good estimation of thermal experiences







Net radiation

$$(1-\rho_{clo}) \times R_{sh}$$ clothed

$$R_{net} = (1-\alpha_h) R_{sh} + \varepsilon_h (R_{ln} - \sigma T_{skin}^4)$$

$$R_{sh} = (A_{top} S\downarrow + A_{bt} \rho_{sur} S\downarrow + A_f (S_T \cos z + \gamma S_D) + \gamma S_D (A_l + A_r + A_{bk}))/A$$

Reflection

Reflectance of ground surfaces

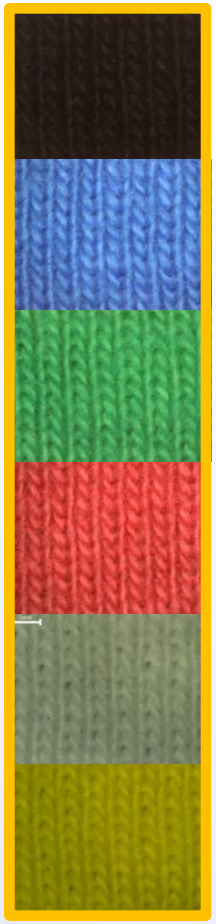
Surface	Reflectance %
Asphalt road (Black)	10.1
Athletic field (Red tartan turf)	15.9
Football field (Green grass)	17.9
Tennis courts (Green Artificial)	13.6
Indoor (Grain wood)	N/A

Dark colored with low, light colored with high in reflectance
Lowest for black asphalt, highest for green grass

Radiative properties of clothing material

100% -Cotton (Same fabric with different color)

Clothing color	Ref. %	Tra. %	Abs. %
Black	17.2	14.3	68.5
Blue	24.5	13.2	62.3
Green	24.5	13.7	61.8
Red	27.9	9.8	62.3
White	42.1	6.1	51.8
Yellow	34.7	8.3	57.0

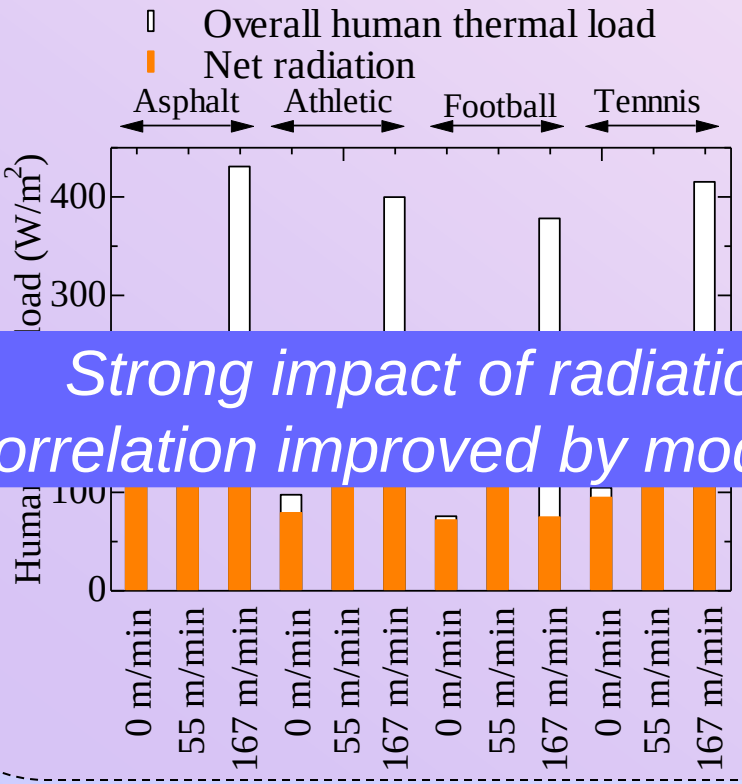


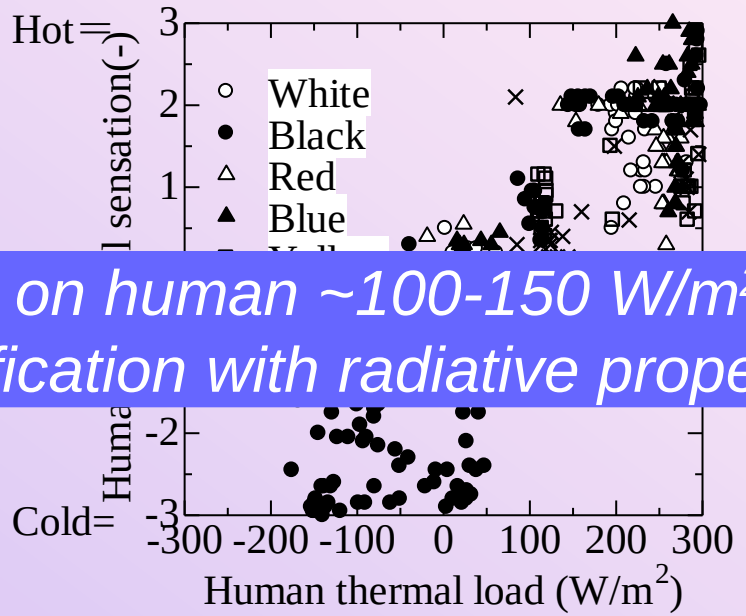
Dark colored with low, light colored with high in reflectance
Almost the same in transmittance
Highest for black, smaller for red, blue…white in absorptance

Human thermal load in summer outdoors

Weather condition during exercise period

Air temp.	Humidity	Wind speed	Solar radiation	Infrared radiation
31.0 ° C	53.9 %	0.9 m/s	704 W/m^2	522 W/m^2





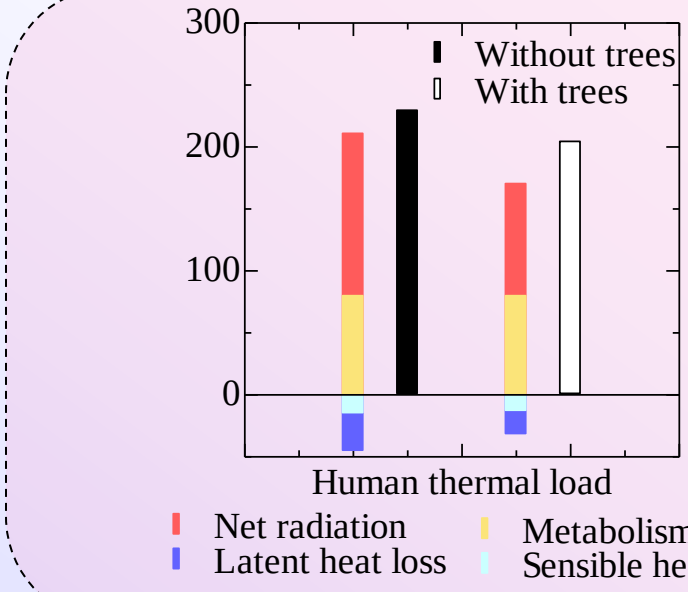
Strong impact of radiation on human ~100-150 W/m^2
Correlation improved by modification with radiative properties

Measurement for different street greenings

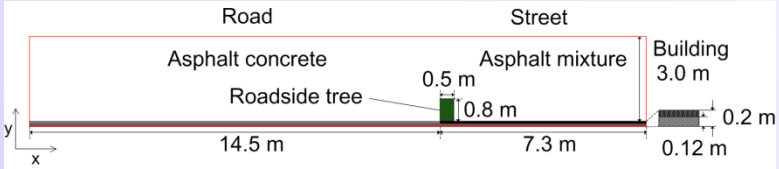
▲Lawn

▲Low height tree

▲High tree wall



Reducing radiation
Improving thermal perception



Detailed comparison in progress

Preparing functional sportswear

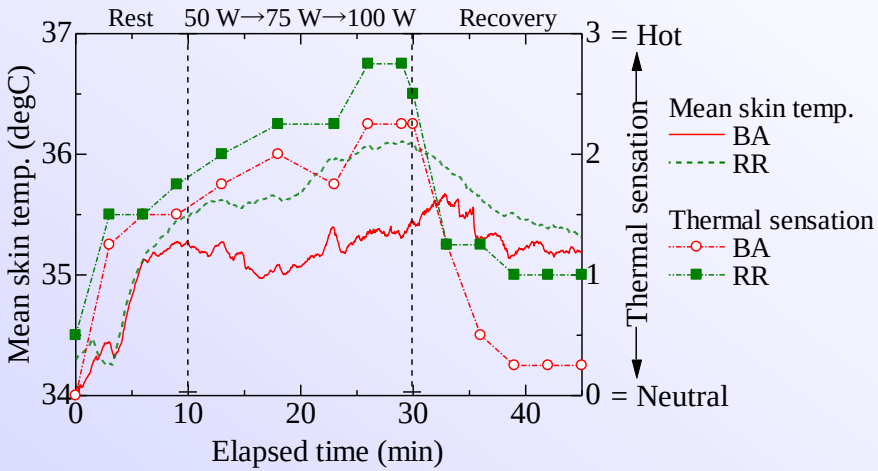
◆Compression garments: CGS

Reflection of Radiation (RR) feature:

Basic (BA) feature:

- Body / motion fit
- Ultra-Violet protect
- Ventilation and moisture control
- Dry-feeling

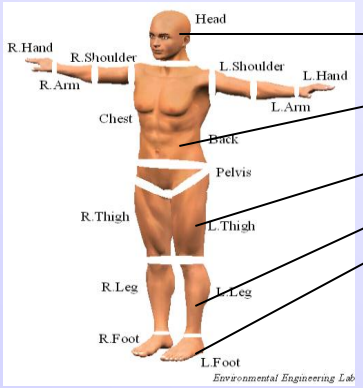
- Reflection of solar radiation



Thermal states improved by functional clothing

Effect of regional thermal load on whole-body

Perception with regional thermal load



Regional TL → Regional TS

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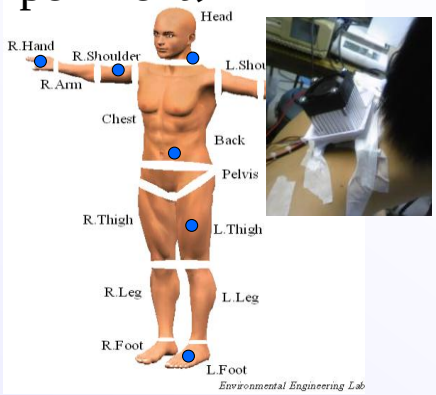
Regional TL → Regional TS

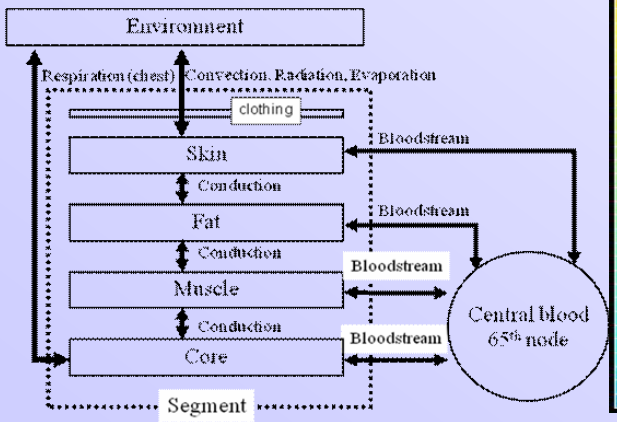
$$TS = \sum_{i=1}^{n} \alpha_i q_i$$ **Whole TS**

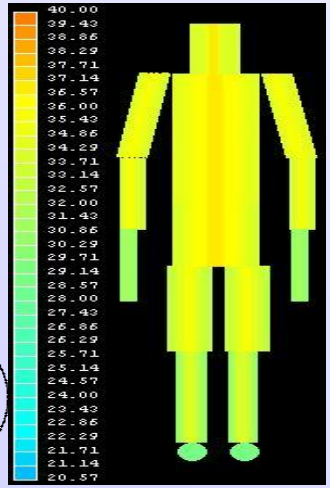
＜Experiment＞



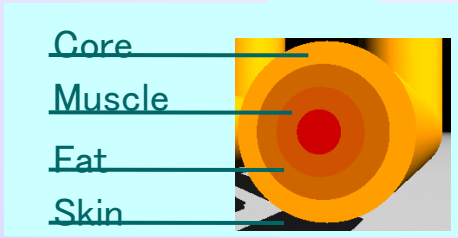
Stimulation at; forehead, pelvis, upper arm, hand, thigh, leg, foot

＜Simulation＞



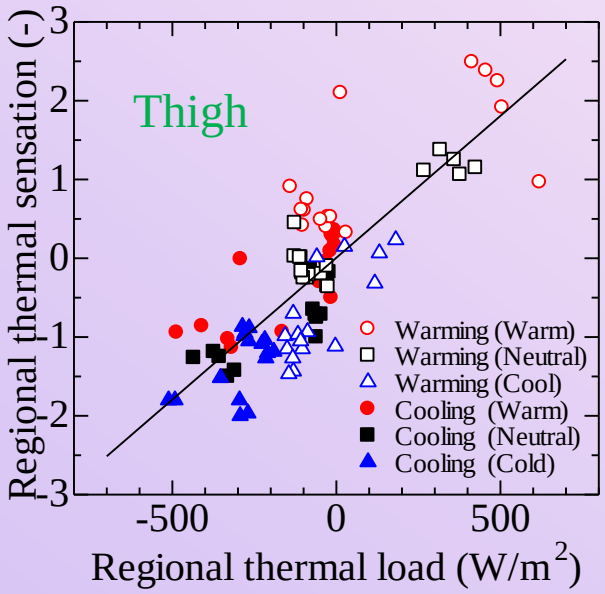


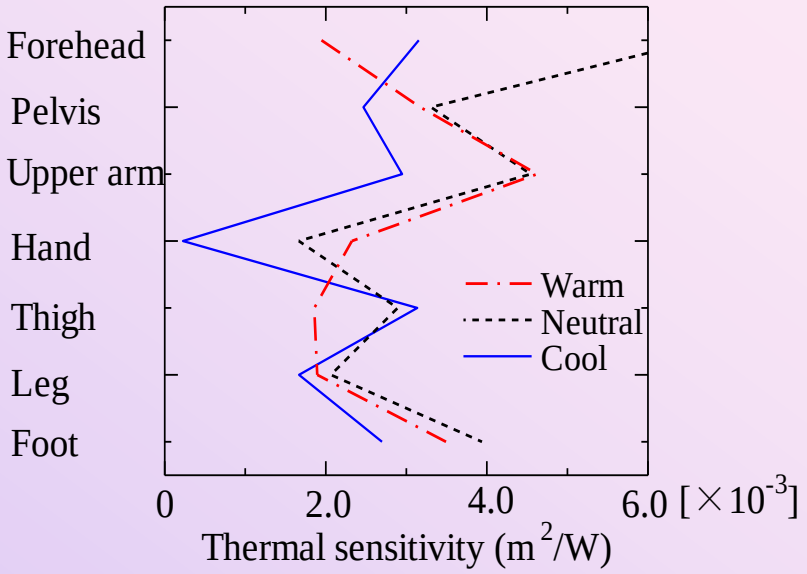
Multi-node human model; (e.g. 65MN)



Regional differences of thermal sensitivity

Ambient; Cool (5 ° C), Neutral (20 ° C), Warm (35 ° C)
50%RH, No solar radiation, Still air





Regional thermal load correlates whole-body sensation
Whole-body sensation formulised by regional sensitivity

Summary and Ongoing project

- Human thermal states in non-uniform thermal load
  - Accuracy improved by considering radiation
  - Modeled human regional differences
  - Providing participants database

Hope to contribute our method with extension from steady state human energy balance model to complex thermal environment to health, safety and active life in outdoor .

  - Development of effective modification for coupling of environment and human non-uniformity as future work

Thank you for attention!!

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